The eye pattern diagram is a proven means of judging the quality of a digital transmission channel or storage medium. It can normally be acquired from every type of CD-ROM player/recorder and can be displayed using remarkably simple equipment.

Design by W. Foede

# eye pattern meter

## measure the quality of home-made CDs

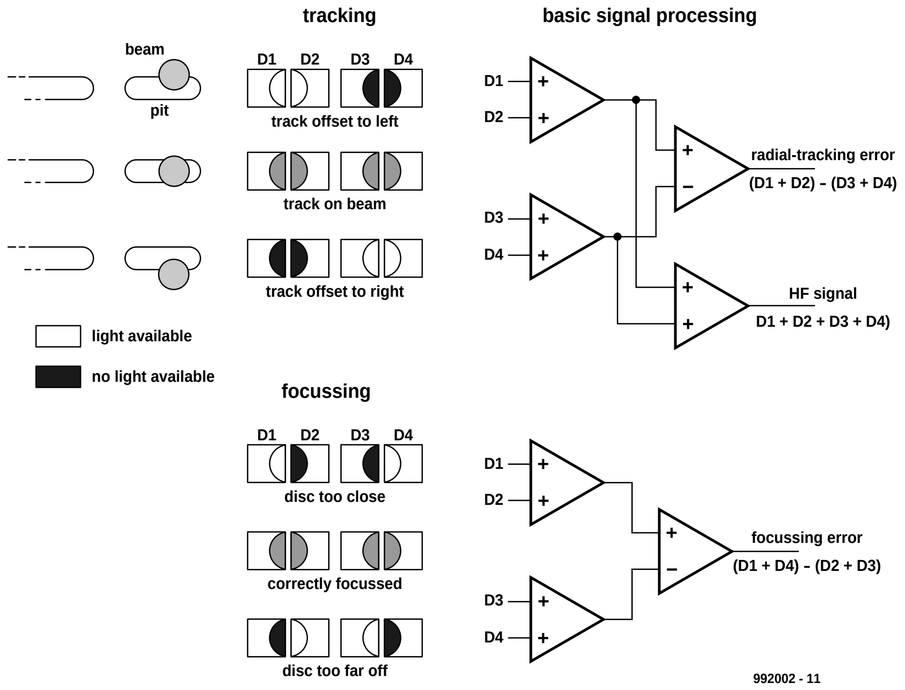

Figure 1. The four photodiodes D1 through D4 provide both the data signal HF and information that is used for adjusting the focussing and tracking.

Nothing is perfect, not even digital data transmission. No matter whether we are dealing with audio data or 'normal' computer data, the error gremlin is always present. Possible sources of errors in digital data transfers can be found both in the system components (such as a CD-ROM player/recorder) and the storage media (such as the CD). Some types of system-related errors, in particular those with electronic sources such as aliasing, nonlinearity and noise, can be minimized by suitable circuit design, and other types can be dealt with by error-protection measures. In the latter case, errors are detected using parity checking or cyclic redundancy checking (CRC) and corrected by means of encoding schemes (such as cross-interleaved Reed-Solomon coding). And if this all fails, the corrupted signal can be restored by interpolation.

Other types of system-level errors are purely mechanical in nature. The causes of the most frequent, commonly-occurring errors with the CD medium are well known: soil and scratches on the surface of the CD itself. These obvious errors usually affect a large number of bits and are referred to as 'bundle errors'. Of course, single-bit errors can also occur, for example due to an asymmetric pit or a material defect. Errors also occur due to faulty tracking and incorrect focussing of the laser beam. It is by no means a simple task to keep the laser beam within micrometer tolerances in spite of often demanding environmental conditions. To ensure a good-quality playback signal, the laser beam should follow the centre line of the track within ±0.1 micrometre. This requires a sophisticated control system and a mechanism that responds quickly and accurately, even after years of service.

There are many possible ways to build a laser read or write head assembly, but all of them have one thing in common. This is the fact that the signal received by the photodetector (that is, the laser detector assembly with its four photodiodes) delivers both the data signal and important information that is used to control the laser head. This information is produced by interpreting the signals from the four photodiodes, as illustrated in **Figure 1**.

The FE signal is used by the focussing actuator to correct for focussing errors, the radial error signals RE1 and RE2 are employed by the tracking control subassembly, and the sum of the signals from all four diodes produces the data signal, designated HF. The latter signal is passed through an automatic gain control stage and converted to a balanced signal before being output from the servo electronics assembly.

There is no need to be concerned about the data signal being affected by the relatively low-frequency control signals. The bandwidth of the data signal is limited to the range of 20 kHz to 1.5 MHz by the eight-to-fourteen modulation scheme (EFM), so it is completely separated from the control signals.

## The eye-pattern diagram

One way to judge the quality of a digital data transfer is to observe its eye-pattern diagram. This is produced (in the case of a CD-ROM player) by connecting the HF signal to the Y input of an oscilloscope while connecting the clock signal recovered from the HF data stream to the X input. This causes an eye-shaped pattern to be displayed. When a large number of such patterns are displayed superimposed, the result is an eye-pattern diagram as illustrated in **Figure 2**. In the ideal case, all of the eye patterns lie exactly on top of each other, but in practice distortions occurs due to radial and focussing errors. Several factors relating to the quality of the digital data channel and the storage medium can be read from the eye pattern diagram. The inner width of the eye is equal to the minimum separation between successive pulse edges of the binary data stream. The difference in the widths of the eye patterns indicates the amount of jitter, and the amount of variation in the pulse amplitude can be read from the difference in the heights of the eye patterns. The inner height of the eye-pattern diagram indicates the noise margin of the digital signal.

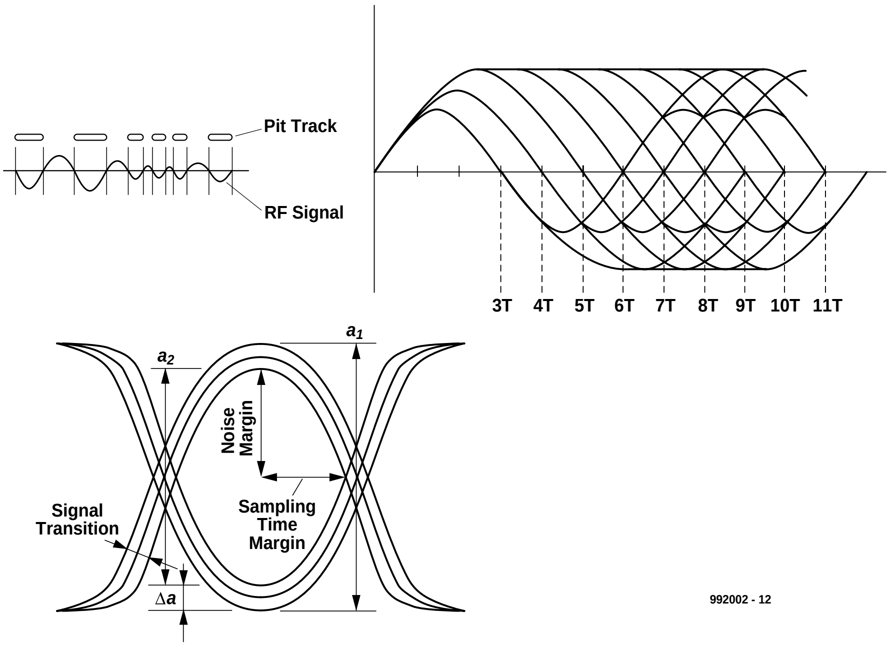

Figure 2. The eye-pattern diagram shows the overall ‘health’ of the data signal.

## Applications

No matter how highly integrated a given CD-ROM player/recorder may be, it is always possible to access the HF and data clock signals somewhere inside the unit. The most interesting application for these signals is to use them to generate eye-pattern diagrams on an oscilloscope, as just described. However, it is possible to do something useful with the HF signal alone (together with an earth reference). The HF signal – once the DC component has been removed – provides in fact an exact indication of the relationship between pit and non-pit signal levels, the ‘pit-to-land ratio’.

You can connect an ordinary moving-coil meter to the HF signal as shown in **Figure 3**, with a capacitor to block the DC voltage and a variable series resistance (R1 plus P1). The Schottky diode D1 acts as a rectifier. The HF signal can easily tolerate this load.

Adjust the resistance so that the meter indication is about 90% of full scale with an arbitrarily selected, prerecorded CD. The meter can be used to optimally adjust a laser head (for a maximum meter indication). This is especially worthwhile for three-beam assemblies, since their mechanisms are not all that robust. However, it can also be used for comparative testing of various makes of CD-R drives (which was the author’s original intention). In this way you can answer questions such as ‘is an inexpensive no-name CD-R drive just as good as an expensive top-brand product?’ and ‘can I find the best brand of CD-R disk to use with a given CD-R drive?’

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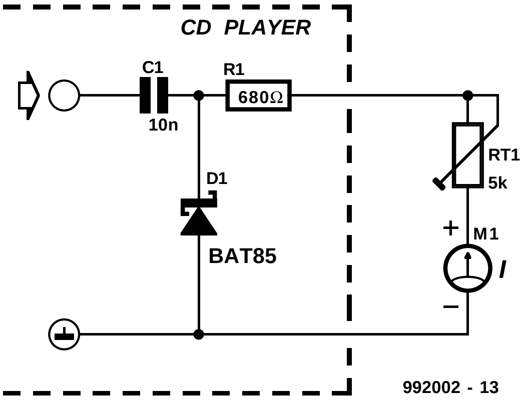

Figure 3. A very simple circuit can be used to show the quality of the data transfer.